to connect private and small organizations cost effectively on an as-needed basis to the Internet backbone, the advantages of the Internet can be much more widely accessible.

CONCLUSION

These areas represent only the beginning of the wide bandwidth communications legacy. It can be expected that affordable, bi-directional wide bandwidth communications, operating in tandem with the revolution in computing, will have as massive an impact on our society as did the earlier revolutions in printing and telephony. While we can try to imagine now the effects of such revolutionary changes, these earlier experiences tell us that we are likely to fall very far short of appreciating their scale and extent. Based on such previous applications, many of the benefits of wide bandwidth communications, because they have been widely discussed, very likely will be realized once these communications are made available.

It is easily envisioned that a portion of the LMDS spectrum might be used in a metropolitan area just to satisfy the needs of the areas listed here. Yet other areas can be expected to arise once the communication capacity is experienced, just as did a wealth of unforeseen applications arise within the telephone infrastructure. The key for LMDS is a large bandwidth allocation, on the order of 2 GHz[1], both to satisfy the initially foreseen applications such as these, and to provide capacity for new application growth.

It is always difficult to predict what the future holds for the final modulation schemes necessary to provide high picture resolution and quality for large screen performances. Nor is it possible to predict which applications will grow first. Frequency planning and distinct allocation within the 2 GHz is premature. This should be allowed to evolve as the market demand for these services develops. It is necessary that the wireless system have the same intrinsic channel capacity as exists in wired (cable and fiber) systems. Otherwise, those interests will inhibit the rapid growth of these wideband new communication opportunities and eliminate their contributions to the public good.

The advent of issuing licenses by competitive bidding is anticipated to raise substantial sums of money for the U.S. Treasury. If LMDS licenses are issued by auctions, potential bidders for the spectrum allocated for LMDS will recognize the great value of the spectrum and will, therefore, be willing to bid higher prices for a 1 GHz block of spectrum than they would for just a portion of that block of spectrum. In this case, due to the wideband nature of LMDS, the whole (1 GHz) is significantly more valuable than the sum of its parts (500 MHz plus 500 MHz). The Commission may very well cripple the goal of its LMDS rulemaking proceeding, namely, to create an immediate and viable alternative to cable, it fails to provide LMDS operators with equivalent tools with which to compete with incumbent cable and fiber operators—thus reducing the value of the LMDS spectrum. We note that some European countries have offered potential operators utilizing millimeter wave technology the full 28 GHz block of spectrum.

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ENDNOTES

1. Due to their differing characteristics, a 2 GHz allocation of an LMDS digital system is equivalent in channel data carrying capacity to a 714 MHz bandwidth cable system.

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November 22, 1993

By Hand

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

Re: Ex Parte Presentation
CC Docket No. 92-297

Dear Mr. Caton:

On behalf of Suite 12 Group ("Suite 12"), petitioner in the above-referenced rulemaking proceeding, enclosed please find two (2) copies of a technical study prepared by engineer-inventor Bernard B. Bossard regarding the current status of digital video compression techniques. The study further explains why Suite 12, with its CellularVision technology for Local Multipoint Distribution Service ("LMDS") utilizing analog frequency modulation, is capable of providing consumers with a high quality, low cost video service that simply would not be available today utilizing commercially available digital compression technology.

The study concludes that application of digital compression technology at the present time to the CellularVision technology for LMDS would not serve the public interest. Current digital compression technology, which produces bit rates in the 2 to 3 Megabits/s range, results in video pictures of inferior quality. Such pictures generally are commercially substandard since they result in picture quality comparable to the quality of an average home video cassette recorder, and substantially below the quality of a standard NTSC television signal. By contrast, the CellularVision technology for LMDS is capable of producing extremely high quality video pictures by utilizing an analog FM format. Comparable picture quality under a digital modulation scheme for LMDS would require a digitally compressed video picture of no less than 10 Megabits/s.

Furthermore, in addition to offering substandard picture quality, the study concludes that digital compression technology that is generally available today is prohibitively expensive. Not until program distributors, broadcasters and cable operators are satisfied with the performance of systems currently being tested, will there be adequate substantial investment in equipment that ultimately will result in low cost digital decoders for consumers.

Accordingly, the study suggests that the allocation of the valuable 28 GHz spectrum today for LMDS, based on optimistic speculation about what digital compression technology may be able to offer in the future, is contrary to the public interest as it will severely inhibit the deployment of Suite 12's exciting and competitive new technology in its infancy. If, in the future, digital compression technology is able to produce high quality video pictures in a low cost, spectrum efficient manner, only then will it be appropriate and in the public interest for a technology such as CellularVision to utilize digital compression technology.

Please place these two copies of this technical study in the above-referenced docket. Any questions regarding this study should be directed to the undersigned.

Sincerely,

Michael R. Gardner

Michael R. Gardner
Charles R. Milkis
Counsel for Suite 12 Group

Enclosures

cc Thomas Tycz, Deputy Chief, Domestic Facilities Division
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Susan E. Magnotti, Esq.

THE CELLULARVISION MODULATION CHOICE

by
Bernard B. Bossard

SUMMARY

The choice of analog frequency modulation for the CellularVision technology for the Local Multipoint Distribution Service (LMDS) developed by the Suite 12 Group is discussed in this paper, along with alternatives such as digital modulation. It is shown that while other modulations, including compressed digital video with complex amplitude and phase formats, might theoretically make more efficient use of the spectrum but at a substantially reduced quality, their application at this time would not be in the public interest. This is because of the reduced video quality which is attendant with present compression technology and the very large increased cost to the average consumer (the public served by the service) of suitable digital decoding and millimeter wave radio equipment. Moreover, the present digital technology is based on the continuance of small screen television, and will not perform adequately in the large screen, multimedia, interactive marketplace of the near future. LMDS represents the only natural competitor to the broadband services pursued by the new telco-cable monopolies. It is noted that as advances in digital techniques and cost effective, more advanced digital equipment ultimately becomes available, they will be phased into the LMDS. However, like the cable expansion plan, the digital format will probably be reserved for more costly, special type services which will be borne by the consumers.

compression at which there is a noticeable deterioration in the picture quality. In fact 2 to 3 Mb/s, generally, is considered representative of an inferior television picture quality, about what might be expected with the playback of an average home video cassette recorder. It would not be commensurate with the quality of a NTSC standard television signal. Certainly, 2 to 3 Mb/s would not be acceptable for larger screens or even for fair resolution, multimedia application.

This 2 to 3 Mb/s picture quality has been demonstrated both to video professionals and the general public, with the generally acknowledged result that it is of a quality inferior to that commonly expected of television. Accordingly, its use is usually limited to applications requiring less critical video performance, such as the transmission of old movies and talk shows. Sports fans and viewers of action films can be expected to be dissatisfied to the point of rejecting programs compressed to that rate.

Importantly, it should be noted that professional broadcasters have only recently, and reluctantly, accepted 45 Mb/s transmission systems as suitable for broadcast back hauls. In Europe, 35 Mb/s systems are now under deployment for similar uses. Either rate far exceeds 3 Mb/s. Future television, multimedia, large screen and surround-sound formats must use larger data rates.

SYSTEMS EVALUATION

An understanding of what is meant by the expression "digital video" is required before evaluation and comparison can proceed. Digital video is not new to the industry. Actually, professional quality frame synchronizers commonly were available in the mid-1970's. These machines adjusted the non-synchronous program video in time by digitizing the incoming video, storing the information in memory in the form of frames, and then reading out of memory and converting back to analog video in synchronization with the desired signal source.

Other digital based machines, including character generators, time base correctors and special effects generators, became readily available in the 1970's. While these machines operated by digitizing the video using sample rates and word lengths which allowed full recovery of the original signal, they thereby required data rates in excess of 100 Mb/s (the "natural rate" for digitizing a NTSC format signal). However, since the signals were not transmitted at these rates, but rather were confined within the digital video within that piece of equipment, no spectrum allocation issues were so encountered. The video transport mechanism remained analog.

A review of the analog NTSC video system reveals that the system is capable of spatial resolutions of 640 pixels horizontally and 480 pixels vertically. Commonly employed compatible formats, however, may employ less than this resolution, especially horizontally, because of reduced transmission bandwidth, and sometimes vertically from loss of interlace. In addition, the NTSC system has temporal resolution of thirty complete pictures (frames) in one second. Compared to the commonly reduced spatial resolutions, the temporal resolution is more than adequate for all but the most rapidly changing scenes. This may be appreciated by recognizing that thirty completely unrelated pictures can be passed through the NTSC analog system in each second; whereas with most programming few changes occur from frame-to-frame within one-thirtieth of a second. Perhaps only a few modern commercial announcements and some programs, such as sporting events and rock videos shown on MTV, constitute the modest universe of material which might challenge the temporal resolution of the analog NTSC television system. At the other extreme, the transmission of a still picture results in enormous video transmission redundancy.

For these reasons both the spatial and temporal statistics of common television programs usually are well below the performance specifications of NTSC analog video transmission, which is very inefficient for a large portion of the air time because of the redundancy of information that it accommodates.

Early attempts to transport video through channels with bandwidths much less than the 6 MHz allocated to broadcast television stations generally were designed to exploit the over-capacity of the system's temporal resolution. For applications such as video phones, frame rates of fewer than one per second might be tolerable. However, since both spatial and temporal resolution requirements vary according to picture content, all the way from the occasional still picture with little spatial detail to the very fast motion and fine picture detail generally associated with most sporting events, clearly any compression scheme based on a fixed information reduction will be unacceptable except for the most limited and least demanding requirements.

Experience in temporal adjustments has been gained from the use of special equipment, such as the Ampex 30 second capacity analog hard disc video slow motion device, often used in the broadcast of sporting events. Further experience has been obtained with the more recent technology in video tape machines having digital picture processors that provide both slow and fast motion. These technological steps have contributed, along with the momentum generated by the unexpected submission of an all digital High Definition TV system (HDTV), to the evolution of what is now included in the field of "digital video compression."

DIGITAL EXPECTATIONS

The purpose of digital video compression is to maximize the amount of information which can be sent through communications channels. However, the primary intent of digital video compression with HDTV was to compact the video bandwidth, whose resolution might otherwise require in excess of 30 MHz, into a single 6-MHz NTSC television channel.

Initial success in digitizing the HDTV signal into a 1200 Mb/s stream and then reducing this to about 25 Mb/s, a reduction ratio of about 50 to 1, stimulated efforts to apply the technique to NTSC video material. It has been common practice to digitize NTSC video using a sample rate of four times the color subcarrier using 8 or 9 bit words, or at three times color subcarrier using 9 or 10 bit words. The common result is a data rate for uncompressed NTSC video in excess of 100 Mb/s.

There has been, and continues to be, enormous efforts toward applying digital compression techniques to NTSC television systems. The desired end result almost always is to increase the capacity of existing video communications channels. Some driving forces behind these efforts include the television program distributors such as major networks and syndicator delivery to TV broadcast stations, and cable program services distributed to headends, all by satellite. These participants are seeking to reduce their distribution costs to their customers by increasing the capacity of their existing channels, while simultaneously maintaining quality of transmission acceptable to their customers. To date, these broadcasters accept only a 45 Mb/s rate, picture quality which obviously occupies more bandwidth than a single LMDS channel.

Other driving forces include cable systems, especially MSOs, who seek to add value to their service by offering more program choices, and additional revenue producing services such as video-on-demand, interactive games, shopping services, banking, etc., all of which require expanded channel capacity.

In summary, the expectation is that digital video compression ultimately will provide increased channel capacity by reducing the transmitted data rate to the minimum that is required to reproduce a TV picture of a quality acceptable to the customer for certain type programs or special added cost services. Suite 12 has been and will continue to monitor the technological progress carefully to determine whether and when this format will be advantageous to our viewers for certain types of programming. The cable expansion, presented in Full Service Network Coaxial Telecommunications Spectrum[1] plan, Figure 1, is similar to that of LMDS.

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[1] H. Allen Ecker, Broadband Com Forum, November 9, 1993.

QUALITY VERSUS EFFICIENCY

Since digital video compression also depends on data reduction to achieve reduced data rates, there is, to the extent of the reduction, an irretrievable loss of video information. Whether that loss produces a noticeably objectionable picture deterioration depends on several factors.

A factor of considerable importance is whether the video program source is live or recorded. A recorded program, whether a motion picture or a video tape, can be compressed off-line; and, given adequate computing power and processing time, it can be digitized and compressed very efficiently. A program producer might provide a pre-compressed version of a motion picture on a data medium at the appropriate data rate ready to be transmitted to the viewers.

On the other hand, a live program must be compressed in real-time. In this application, the compressor can have no *a priori* knowledge about the video signal, as, for example, when rapid motion suddenly transforms an otherwise nearly still scene in sporting events. This is the more challenging condition for the temporal resolution of the compression algorithm, which must reproduce the rapid motion without serious degradation of the signal, and do so in real-time. Anything less will result in highly visible motion artifacts, which are hardly acceptable, especially to the professional program distribution industry.

Experience to date supports the conclusion that to perform compression on real-time video program material, pass it through a transport medium, and perform a real-time decompression and faithful reproduction of acceptable picture quality with minimal observable motion artifacts, requires the compressed data rate to be about 10 Mb/s.

K. Kelkar, of the General Instrument Corp, in his paper entitled "Digicipher" describes how the system has been optimized for satellite (DigiSat) and cable (Digicable). This paper reveals that there are very different transmission behaviors of the two media.

DigiSat can compress up to 10 channels of NTSC or PAL video, or up to 24 channels of compact disc (CD) quality audio, together with conditional access data, into a single 27 Mb/s data stream. This corresponds to 2.7 Mb/s for NTSC and 1.2 Mb/s for CDI. However, Kelkar also states that "Given the more demanding nature of video-sourced material with much movement, programming such as sporting material can be transmitted [within] 4 channels of NTSC or PAL to a transponder, with little subjective loss of video quality." This acknowledges that some motion artifacts are noticeable even at 6.75 Mb/s. This supports our conclusions that digital compression to the 3 Mb/s rate for a regular television program channel is not practical without supporting Suite 12's conclusions presented in the present paper.

STANDARDS

Video compression standards such as MPEG-1, MPEG-2, and related standards have been the focus of the video community during the past several years. Significant advances have been made toward the establishment of standards that will enable multi-vendor compatibility in the transmission, reception, storage, and playback of digitally compressed video information. The cable and satellite industries especially have been awaiting the "finalization" of MPEG-2 standards.

Industry analysts now envision multiple versions of MPEG-2 oriented toward proprietary implementations by the vendors and according to the application, such as whether delivery is by ATM, ADSL, DBS, and so forth. While such multiple solutions show an important trend, the lack of a common and inexpensive home decoder as well as delays in the availability of MPEG-based systems makes any near-term implementation impractical. MPEG-based systems probably will be utilized first in the satellite delivery of programming to cable head ends and broadcast stations. Until program distributors, broadcasters and cable operators are satisfied with the performance of these systems, it is unlikely that there will be significant investment in MPEG equipment.

Suite 12 fully recognizes the importance of MPEG and related standards in the evolution of digital video delivery systems, and continues to closely monitor how MPEG can be used to provide enhanced services to CellularVision users. However, a timely roll out of the LMDS service must not be delayed in anticipation of the availability of low cost digital decoders. Still, LMDS should have the same natural bandwidth intrinsic to cable networks, which implies the need for even greater bandwidth than the 1 GHz per operator requested in the LMDS rulemaking proceeding.

A valid comparison of our present LMDS service using FM analog technology to the not-yet-available digital compression technology must be made based on formats which yield equally acceptable picture qualities. At this time, for comparable quality to the LMDS format, a digitally compressed video program must be compressed to no less than 10 Mb/s.

TYPE OF DIGITAL MODULATION

It is clearly desirable to use the most spectrally efficient modulation in order to maximize the capacity of a band limited system. Spectral efficiency is expressed in Bits/sec/Hz, with higher values representing increased efficiency. Table A shows the key parameters for various likely schemes.

TABLE A

MODUL. SCHEME	EFFICIENCY Bits/Sec/Hz THEOR.	FEASIBLE	C/N dB	Mb/s in 18MHz CHANNEL	CHANNEL SPACE for 10.5Mb/s (MHz)
4 PSK	2	1.25	13	22	10.0
16 QAM	4	2.5	21	44	5.0
32 QAM	5	3.0	24	54	3.5
64 QAM	6	3.75	26	67	3.1

The use of higher level schemes is clearly attractive because of the promise of extra capacity. For this reason, 64 QAM has been targeted by some cable systems for use in digital TV systems. Since cable systems are closed to external influences, and the CellularVision system is technically quite different, we will now analyze the effects of using these modulations in a microwave LMDS system.

The practical bandwidth efficiency is much lower than the theoretical value for various reasons, some of which are common to most digital implementations and some special to the microwave LMDS case. In theory, the bandwidth occupied by each television channel can equal the channel spacing without provision for adjacent channel interference (ACI). In practice, it is necessary to use filters with a moderate "rolloff". In this way we can prevent adjacent channel interference while specifying a filter that can be manufactured practically. For example, to meet FCC mask requirements for line-of-sight microwave transmission, the rolloff factor is usually near 0.5, yet this alone reduces the spectral efficiency by 25%. This efficiency reduction is in line-of-sight equipment wherein lowest cost is not as critical to serve the public good as it is in a system such as LMDS, designed to serve the home consumer.

Similarly, in the LMDS, the aim is to pack television carriers as close together as possible without causing harmful ACI. We must therefore take into account the imperfections of microwave transmissions, both in terms of affordable equipment and the transmission scenario. In a microwave transmitter, the raised cosine filtering only can be implemented at the input to the modulator, and other distortion or noise effects generated subsequently in the transmitter chain are not corrected. The higher bandwidth efficiency modulation schemes are particularly affected by the resulting signal imperfections.

Bandwidth efficiencies close to theoretical have been achieved in point-to-point, line-of-sight microwave links, but only by expensive engineering at both the transmitter and receiver. For example, it has been found necessary to include complex adaptive equalizers in the receiver. In the interests of serving the common good for many recipients, it is necessary to operate with less critical parameters. The practical bandwidth efficiencies obtainable are approximately those shown in the table above. LMDS is a point-to-multipoint system that employs consumer-priced receivers while delivering as much spectral efficiency as practical.

TRANSMITTER TECHNOLOGY

The transmitter must handle numerous simultaneous channels. Even though some channels may be digitally multiplexed, it is not feasible to put them all on the same carrier, and so the transmitter is required to amplify multiple carriers without the non-linear effects that would cause distortion and harmonics. To operate the transmitter as a linear amplifier, it must be operated at less than its output tube's maximum output power. That is, the microwave transmitter must be backed-off to avoid intermodulation products.

For analog FM TV transmissions as used by the LMDS, a backoff of 7 dB from full output provides sufficiently linear operation. For a 4-level modulation, which requires approximately the same carrier to noise ratio as the FM analog receiver, the same degree of backoff is sufficient. But higher level modulation schemes necessitate lower tolerable intermodulation distortion levels and a correspondingly greater backoff. That is, the transmitter must be operated at a still smaller percentage of its rated full power. From experiments using 32 QAM, it is found that a backoff of at least 12 dB is required. Also from the table, it is seen that 64 QAM requires a 13 dB better C/N than 4 PSK. To achieve the same range as the analog FM system, we would require a 28 GHz transmitter having a minimum 18 dB higher peak power rating to accommodate the same cell size. This is not feasible. The only alternative would be to reduce the cell size to a totally non-economic extent. Further consideration of timing jitter, phase jitter and co-sign roll off may add additional linearity requirements of up to 6 dB. This would result in a maximum cell diameter of 0.7 miles, compared to 4.6 miles. The Budget Comparison (Table B) shows how the cell diameter depends on the modulation type. The cell diameter for 64 QAM is less than one-third of that for either analog FM or 4 PSK. This means that the cell area, being proportional to the square of its radius, would be reduced by a factor of 10. It is important to note that even if the necessary high power transmissions for 64 QAM could be achieved, the cell diameters would still have to be reduced because the Desired to Undesired Signal Ratio for 64 QAM is so much greater than for analog FM or 4 PSK.

TABLE B

Budget Comparison

	ANALOG FM		4 PSK	64 QAM	AN
Channel spacing (MHz)	20	16	10	3.33	
Noise bandwidth (MHz)	18	14.4	8.5	2.8	5
Thermal noise (dBm)	-101.5	-102.5	-104.5	-109.5	-106
Noise figure (dB)	6	6	6	6	
C/N (dB)	13	13	13	26	[illegible]
S/N (dB) (faded)	42	37	N.A.	N.A.	[illegible]
RX sensitivity (dBm)	-82.5	-83.5	-85.5	-77.5	-45
TX power/channel (dBm)	+23	+22	+20	+8	+
TX antenna gain (dBi)	+10	+10	+10	+10	+
RX antenna gain (dBi)	+29	+29	+29	+29	+
System gain (dBi)	+144.5	+144.5	+144.5	+124.5	+95
Cell diameter (miles)	4.6	4.6	4.6	1.4	0.
Relative cell area (normalized)	1	1	1	0.04-0.09	0.00
Unfaded S/N (dB)	53.5	48.5	N.A.	N.A.	

Notes

1. Cell diameter defined by 99.9% availability, i.e. 5 dB/mile
2. Carson's rule plus 10% overdeviation

3. Video receiver transfer function

$$= 10 \log 3\left(\frac{Df}{fm}\right)^2 - 10 \log \left(\frac{Bn}{2Bv}\right) - W - CF$$

4. NTSC unified weighting (W) 12.8 dB
5. RMS to peak/peak luminance factor (CF) 6 dB
6. 100 W unlinearised TWT transmitter backed off 10 dB to give a transmitted C/I of 30 dB so as to make a small contribution to total received C/I for system of 23 dB.
7. Transmitter antenna omni-directional azimuth, 1.5° elevation.
8. Receiver antenna 6 inch square patch at 40% efficiency
9. No long path rainfall reduction applied at 3 miles to conform to new CCIR recommendation.
10. Analog AM requires 18 dB TWT backoff to reach 55 dB chrominance/luminance separation. Even if no additional backoff over analog FM is provided, the cell diameter would only reach 265 yds. (0.15 mile)
11. 4 PSK and 64 QAM assume 10 Mb/s, as this is necessary to give equivalent subjective quality of sport/moving picture content.
12. The C/N for QPSK corresponds to 10-5 BER.
13. A 5% overhead for Hamming code or similar forward error correction has been used.
14. A practical spectral efficiency for QPSK 1.25 Bit/sec/Hz has been assumed to allow for millimeter wave oscillator and filter difficulty.
15. TWT backoff for QPSK is 10 dB (Microwave Digital Radio, IEEE Press)
16. Spectral efficiency of 64 QAM is assumed to be 3.75 Bit/sec/Hz.
17. The C/N for 64 QAM corresponds to 10-5 BER.
18. TWT backoff for 64 QAM is assumed 18 dB (Microwave Digital Radio, IEEE Press)

Only limited-power transmitters having 100 watts of total output power are economically available for the 27.5-29.5 GHz band. Since power is limited, it is necessary that the signal format schemes they employ result in as close to constant power output envelope as possible. A recent article in IEEE Communications (Vol 29. No 12, 12/91) discussed major classes of trellis modulation codes. Energy-bandwidth performances were compared to determine bits/Hz tradeoffs. Constant envelope-coded modulation primarily works in the low energy-high bandwidth region of energy-bandwidth. "...Codes that perform in the narrow-bandwidth/high-energy part of the plane need to code both signal phase and amplitude in order to be efficient (or so it seems at the present state of the art). Phase-only codes (which result in nearly constant power output by the transmitter) of this kind may someday be discovered, but none exist now, and there is every evidence that amplitude variation is a critical factor in bandwidth efficiency..." Thus, considering the present state-of-the-art and the improvements that can be anticipated, it appears that constant envelope coded modulation techniques will provide spectrum efficiency of no more than about 1.5 - 2 bit/s/Hz.

INTRODUCTION OF DIGITAL TRANSMISSIONS

Note that the bit rates given below are not exact: the precise values adopted will depend on the cost/efficiency trade-off valid at the time when the first conversions are made. (They may also be slightly adjusted to match any other standards for which compatibility might be advantageous such as broadcast satellite transmissions and any emerging standard rates for video encoding. HOWEVER, THE VALUES GIVEN ARE ACCURATE ENOUGH TO VALIDATE THE ARGUMENTS ADDRESSED IN THIS PAPER.

The previous sections show that 4 level modulation is the maximum practical for LMDS at microwave frequencies. We will now show how digital transmissions, once proven to be viable and cost-efficient, can be introduced into a pre-existing analog CellularVision system.

The change to digital will be phased in over many years; thus we will convert one or two 20 MHz analog channels at a time.

Options would then be:

One analog channel to:

- One 20 Mb/s transmission, or
- Two 10 Mb/s transmissions, or
- Three 7 Mb/s transmissions, etc., or

Two adjacent analog channels to:

- One 40 Mb/s transmission, etc.

Since the consumer's receiver (and for bi-lateral operation, transmitter equipment as well) must be economically viable, it is expected that this equipment can demultiplex digital signals at rates up to a few tens of Mb/s. Therefore, we can convert one or two analog channels into digital transmissions at 20 to 40 Mb/s and then digitally multiplex various rate services on to these transmissions.

For example, a high definition television (HDTV) service might use all, or nearly all, of the bit stream. Alternatively, a single digital transmission might be used for two or three standard TV channels, ten low quality channels, or a mixture of these. Changing to digital transmission gives much more flexibility in providing services but the bandwidth savings are very dependent on the quality of the video services provided.

COMPARISON WITH DIGITAL CABLE SYSTEMS

When compared to LMDS, the key advantages of the digital cable system are:

- Propagation loss in the cable is much less than for an omni-directional radio wave, and cell-to-cell interference is not a problem. Thus, better signal to noise and interference ratios are available at the receiver.
- The signals are transmitted in the frequency domain below 1000 MHz where linear power amplifiers are economically available.

For these two reasons, it is possible for a cable system to transmit higher order digital modulations such as QAM, with the result that more bits per second are available and, hence, more capacity may be enjoyed in the 1000 MHz or lower frequency domain available on cable.

The proposed Full Service Network Coaxial Telecommunications Spectrum plan, Figure 1, essentially maintains the existing cable distribution spectrum usage up to 450 MHz. This strategy allows the present AM type service to continue to all customers without the need for premium pricing. In other words, even at low frequencies in the cable approach, no digital technology is planned for the first 450 MHz. This area of service will be unchanged for the foreseeable future. Only in a limited portion of the cable band will digital be employed and that at considerable premium pricing to the consumer.

The proposed digital services with various supporting hardware may begin in the cable spectrum above 450 MHz and be provided at a much larger customer cost, probably between $400 and $1000, for initial equipment. The plan envisions about 300 digital channels of 3 Mb/s each in about 250 MHz plus about 300 MHz of 2-way communications services. Comparatively, at the reduced bits/sec/Hz rate of LMDS systems, the same 300 digital channels would require spectrum in excess of 700 MHz.

The significance of this data is that digital services, even when offered on the mature technology of cable television, are used only to provide premium services to viewers and at significantly greater cost. This digital technology should not be imposed upon LMDS in its infancy and be required a general purpose service designed to offer a lower cost option to viewers except as a premium service offered optionally to the smaller number of viewers willing to pay its added cost, or a special data network designed for cells covering areas which do not have the need for video services (i.e., Wall Street).

COMPARISON WITH SATELLITE BROADCASTING

Like LMDS, satellite broadcasting operates at microwave frequencies and has similar transmitter linearity problems. This means that it is necessary to employ constant envelope, or near constant envelope, modulation schemes. Thus, both satellite broadcasting and LMDS will be restricted to efficiencies of 1 to 2 bits per second per Hz and will use similar bandwidth channels for a given service.

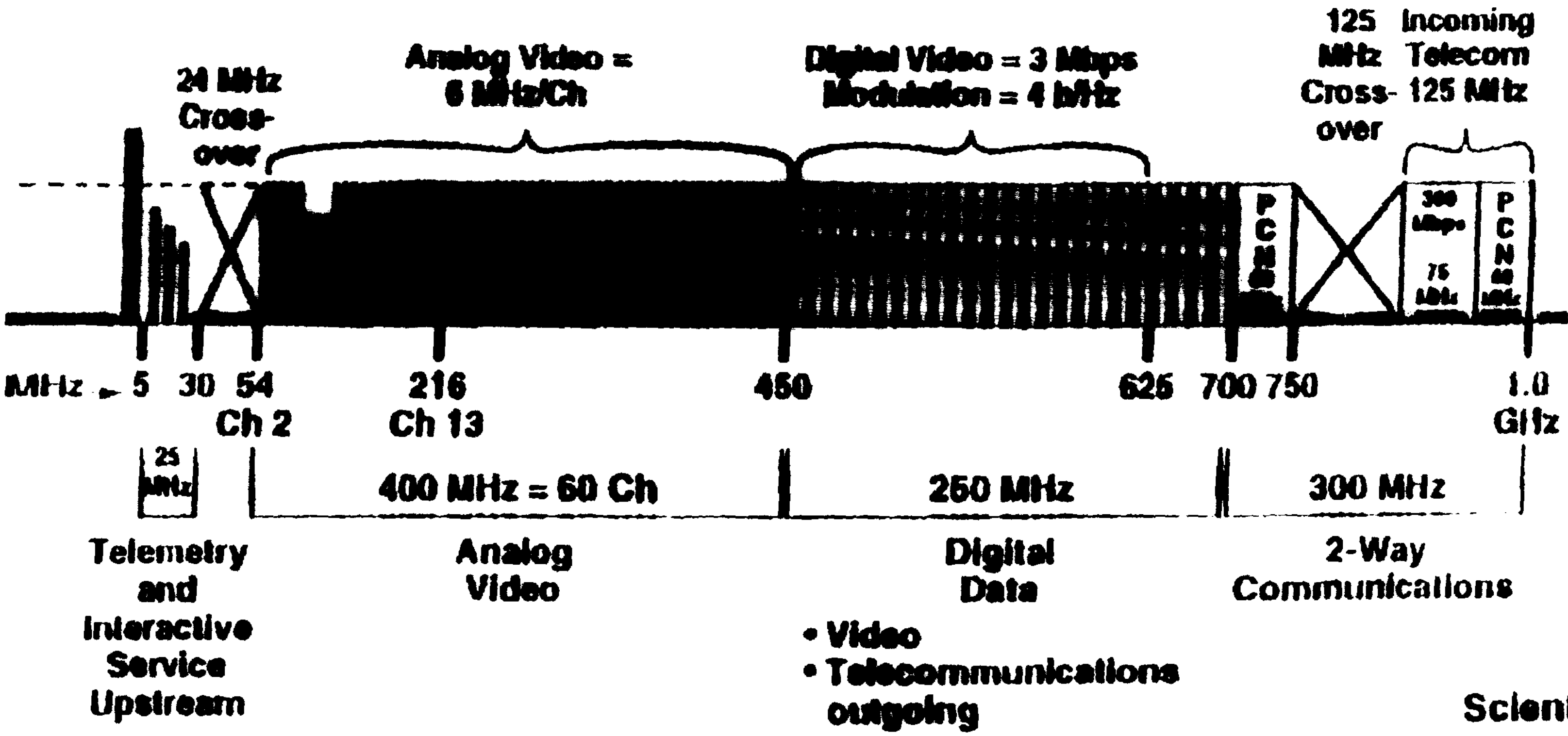
However, because the cell size in LMDS is much smaller than the footprint of the satellite, LMDS is much more efficient in frequency reuse. In cases of wide area coverage, this is not an advantage. However, when only local coverage is needed LMDS provides a strong gain in spectral efficiency. This is especially true in interactive applications or video-on-demand wherein only a single customer may be using a channel. Thus, for LMDS, specialized programming, advertising and interactivity can be designed on a demographic cell-by-cell local basis, rather than on a national basis.

Moreover, by definition, LMDS signals must be of sufficient quality in order to be repeated into the adjacent cells without interference or distortion. A satellite DBS system is a single cell, and does not encounter these additional problems. The LMDS solution of polarization reversal allows for adjacent cell isolation the LMDS concept to be economically viable.

VIDEO CODING

VIDEO DATA RATE Mbits/s	ATTAINABLE COMPRESSED RATE Mbits/s	CODING METHOD	SERVICE	PICTURE QUALITY	CABLE	BROADCAST	SATELLITE	CELLULAR VISION	VENDORS	AVAILABILITY	NOTES
	0.012-0.016	DCT-Based Proprietary	POTS Video Phone	Very bad					ATT Marconi	Now	
	0.064-0.384	CCITT H261 Motion Compensated DCT	ISDN Video Phone & Video Conferencing	Poor@64 Kbits/s tolerable @ 384 Kbits/s					British Telecom CLI, etc.	Now	An H.261 decoder is similar to MPEG-1 decoder, large volume costs would be similar
>100	1.2	MPEG-1	CDI CDROM ADSL	VCR Quality VHS-Like					LSI Logic/ C-Cubed Motorola/Philips	Now	Decoder chip + 2 [illegible] dram - trade range vs bit rate
>100	2-3	MPEG-2	Cable - DBS Direct TV, etc.	Not as good as domestic NTSC TV	8-12 video ch/6MHz 4 bits/s/Hz	4-6 video ch/6MHz 2-3 bits/s/Hz	CPM or QPSK Constant Envelope ≥ 2 bits/s/Hz	28Ghz Power Device non-linearity requires constant envelope signals to achieve efficiency	ST/LSI Logic C-Cubed	Prototype Hdw Now Prototype products 1994 Production ramp up 95-98	Availability of Real-time encoders is a critical isue
>100	4-6	MPEG-2	Cable - DBS Direct TV	As good as NTSC	Same mod 64 QAM or 16 VSB	16 QAM or 4 VSB Amplitude Non-linearity	Same depends on S/N & margin		as above	as above	Same decoder - MPEG-2
>100	10	MPEG-2	Cable - DBS Direct TV Satellite Distribution	CCIR 601 component Studio quality (640 x 480 pixels)	Same mod	Corrupts data S/N tradeoff	Same as above	CDM, QPSK or FM 0.7 - 1 bits/s/Hz	as above	as above	as above
>1200	24	MPEG-2+	Terrestrial & Satellite HDTV	Excellent Quality TV (1920 x 1080 pixels)	4 bits/s/Hz 32 QAM 64QAM 4VSB	32 QAM 4 bits/s/Hz (6MHz ch)	QPSK/CPM FM/FSK 1-2 bits/s/Hz	FM, CPM QPSK Same as satellite	Grand Alliance	?? 197? 2000??	

The Full Service Network
Coaxial Telecommunications Spectrum



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